A composite image featuring a sounding rocket in orbit above the Earth's cloud-covered surface. The rocket is shown in a cutaway view, revealing internal components. The text is overlaid on this image.

Temporal variation in the Ly-alpha linear polarization observed with the CLASP sounding rocket

CLASP

Chromospheric Lyman-Alpha SpectroPolarimeter

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J. Trujillo Bueno (IAC), and CLASP team

NASA sounding rocket experiment

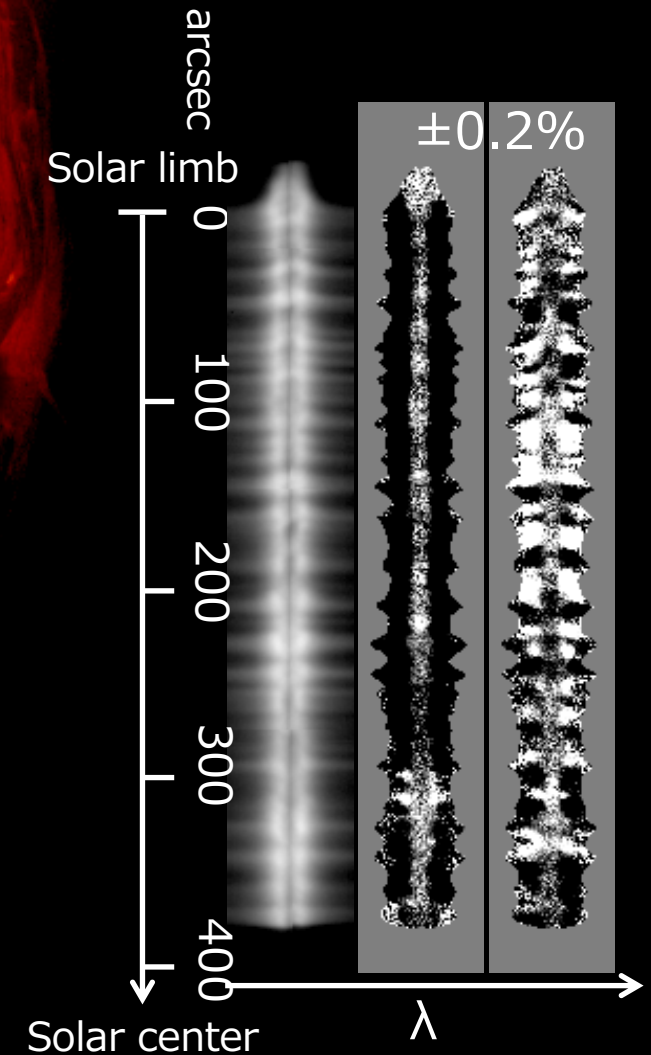
Chromospheric Lyman-Alpha Spectro-Polarimeter

1. High-precision ($<0.1\%$) spectro-polarimetry in VUV
2. First detection of scattering polarization in the Ly α line (121.6 nm)
3. Exploration of magnetic fields in the upper chromosphere and the transition region via the Hanle effect



Data observed with CLASP

- Polarization spectrum in Ly-alpha (121.567nm)
 - Spatial sampling: 1.11 arcsec
 - Spectral sampling: 0.0048 nm
 - Measured polarization: linear polarization (I, Q, U)
 - Modulation duration: 1.2 sec
 - Observation time:
 - Disk center: 10 sec
 - Solar limb: 280 sec



Purpose of this study

- The Ly-alpha polarization signal taken by the CLASP contains the information about the radiation and magnetic fields in the chromosphere.
 - CLASP data is wonderful!!
 - High accuracy in polarization measurement ($\sim 0.1\%$)
 - High stability in the pointing (attitude control)
- ➔ Hence, in order to derive the information about the chromospheric magnetic fields, we examine the **temporal variation** in the Ly-alpha linear polarization.

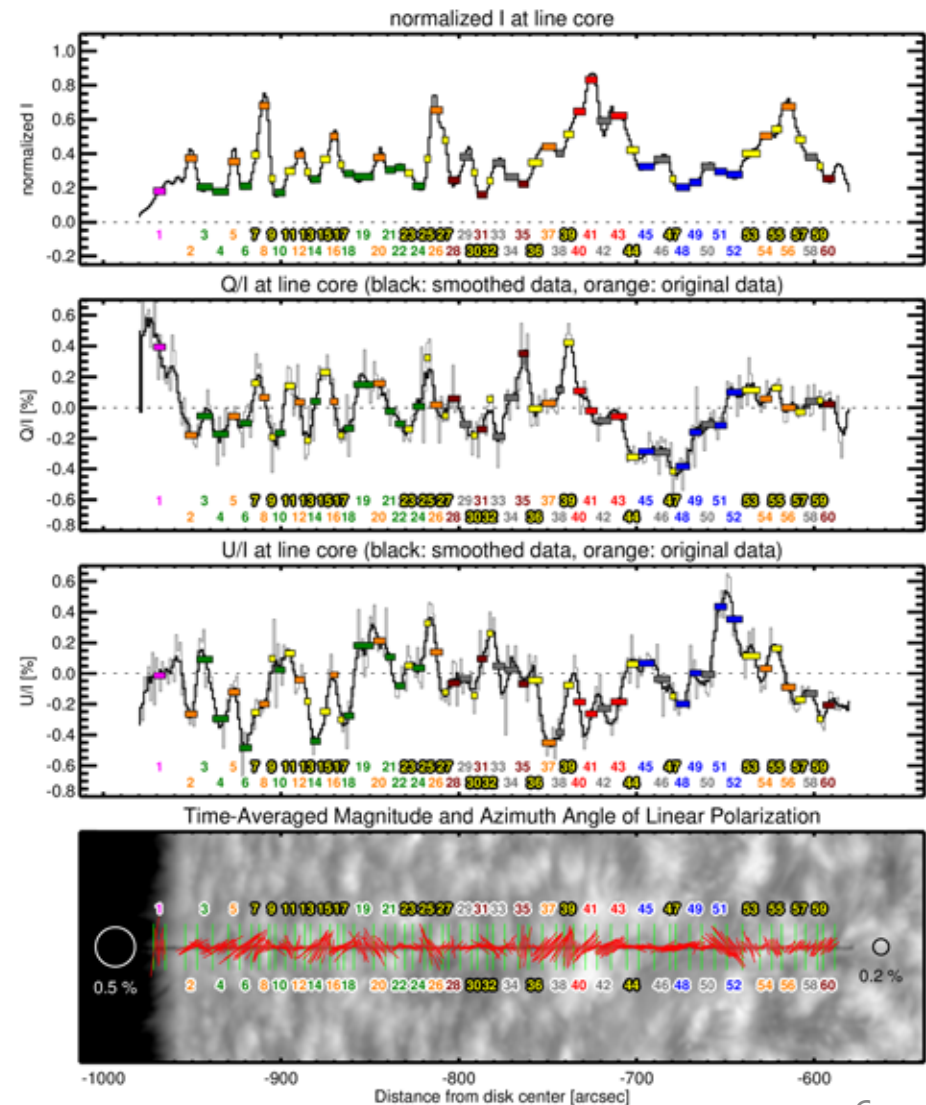
Data process

- **In order to achieve the polarization accuracy of " $2\sigma \sim 0.1 \%$ ", we perform the following processes:**
 1. We sum up the data taken with two channels.
 2. We perform the spatial, temporal and spectral binning.

Spatial binning

- We classify the SP data along the slit into **8 categories** based on the intensity profile. Consequently, the slit is divided into **60 regions** (~ 6 arcsec). We perform the spatial binning for each region.

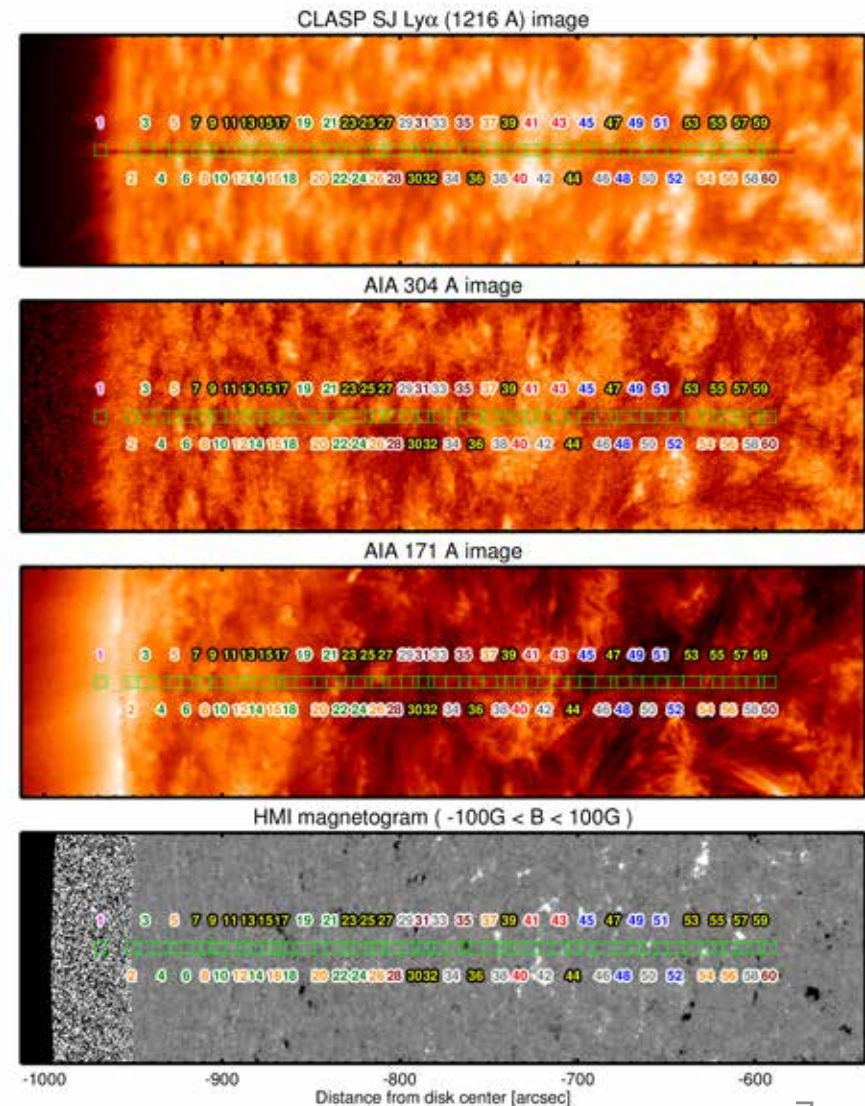
“enhanced network”, “network”,
 “inter network”, “boundary”,
 “filament”, “fibril”, “intermed.”,
 “spicule”



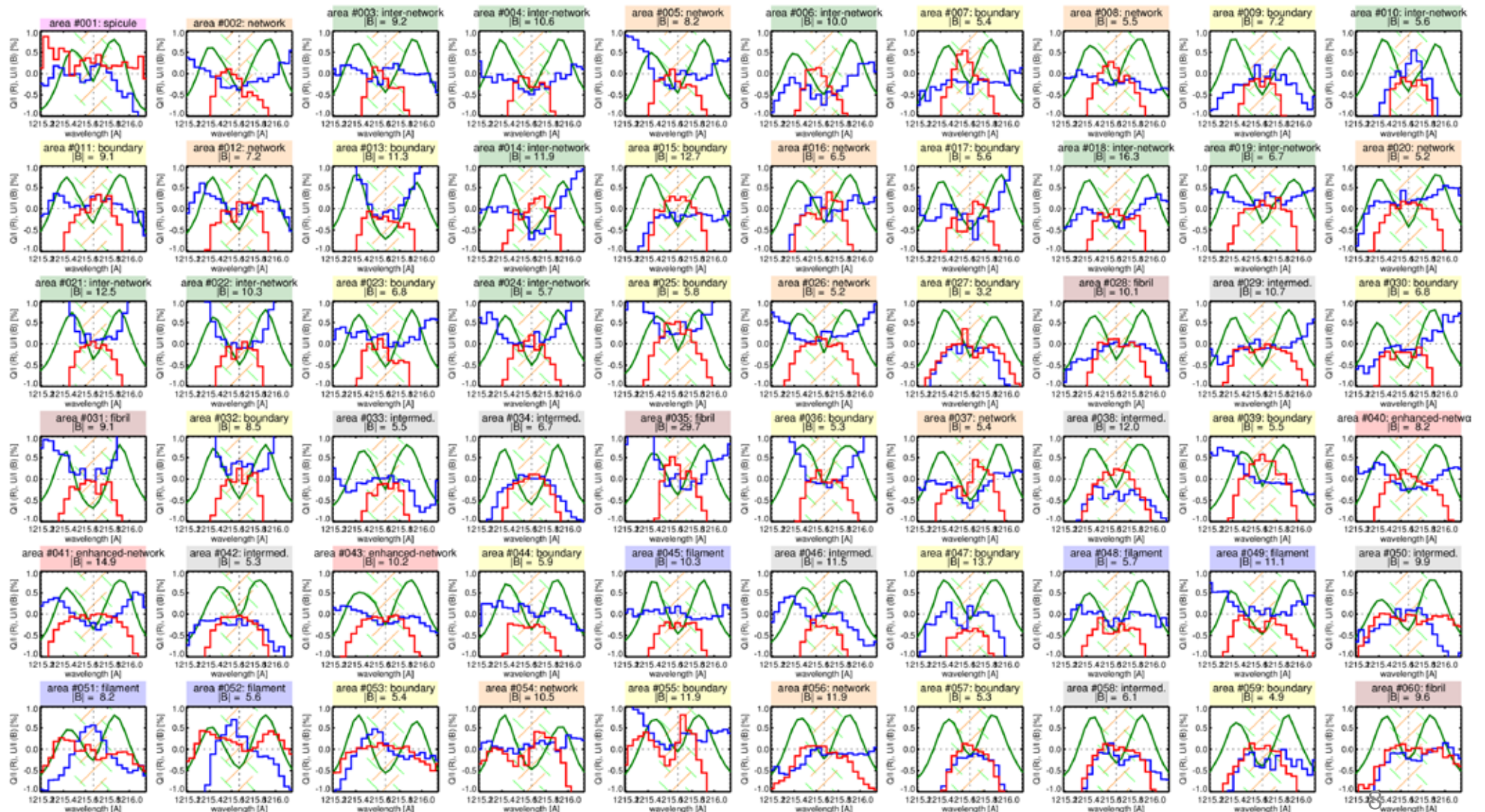
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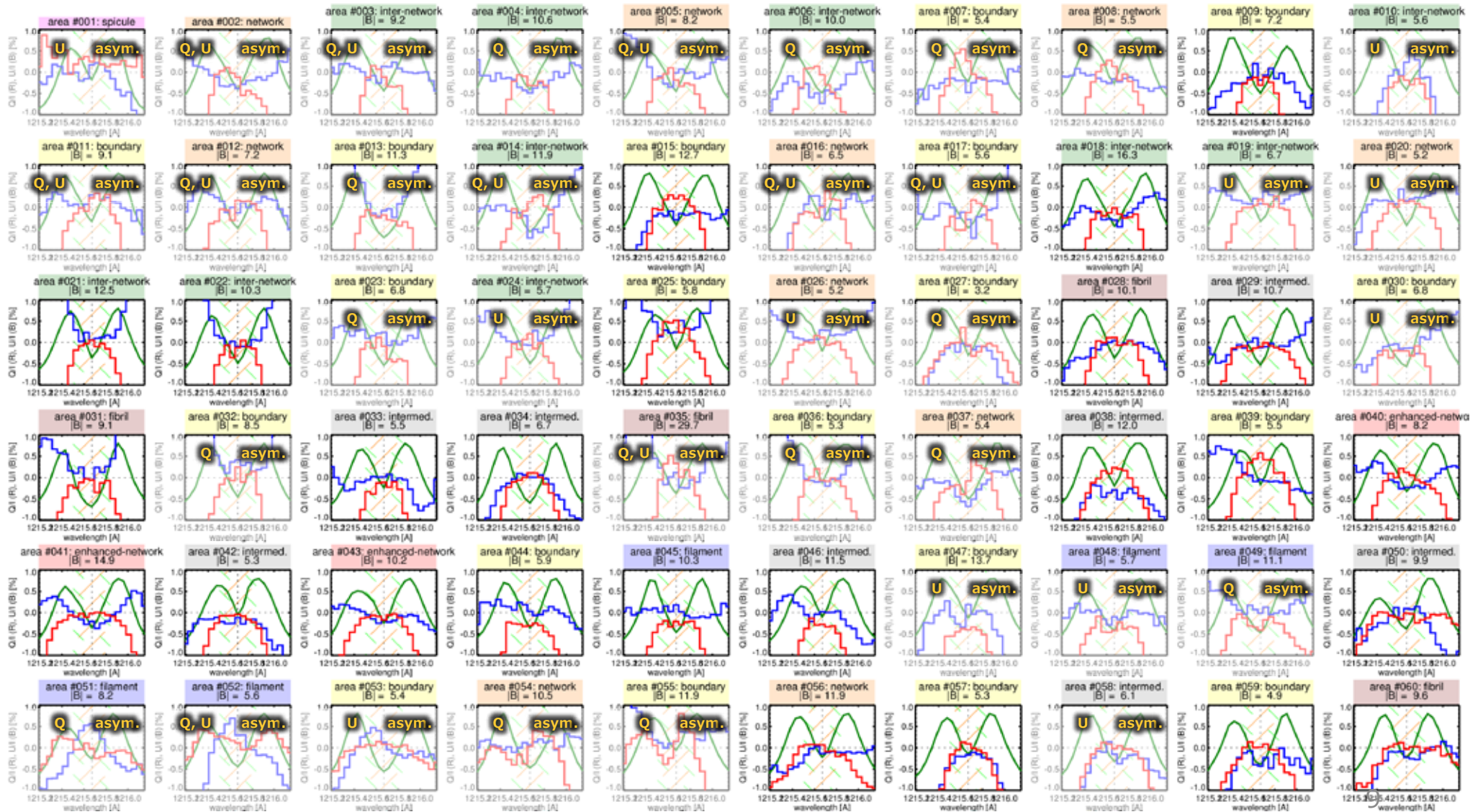
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Linear polarization spectrum for each region



Linear polarization spectrum for each region
 → The asymmetry (asym.) is seen in some regions.



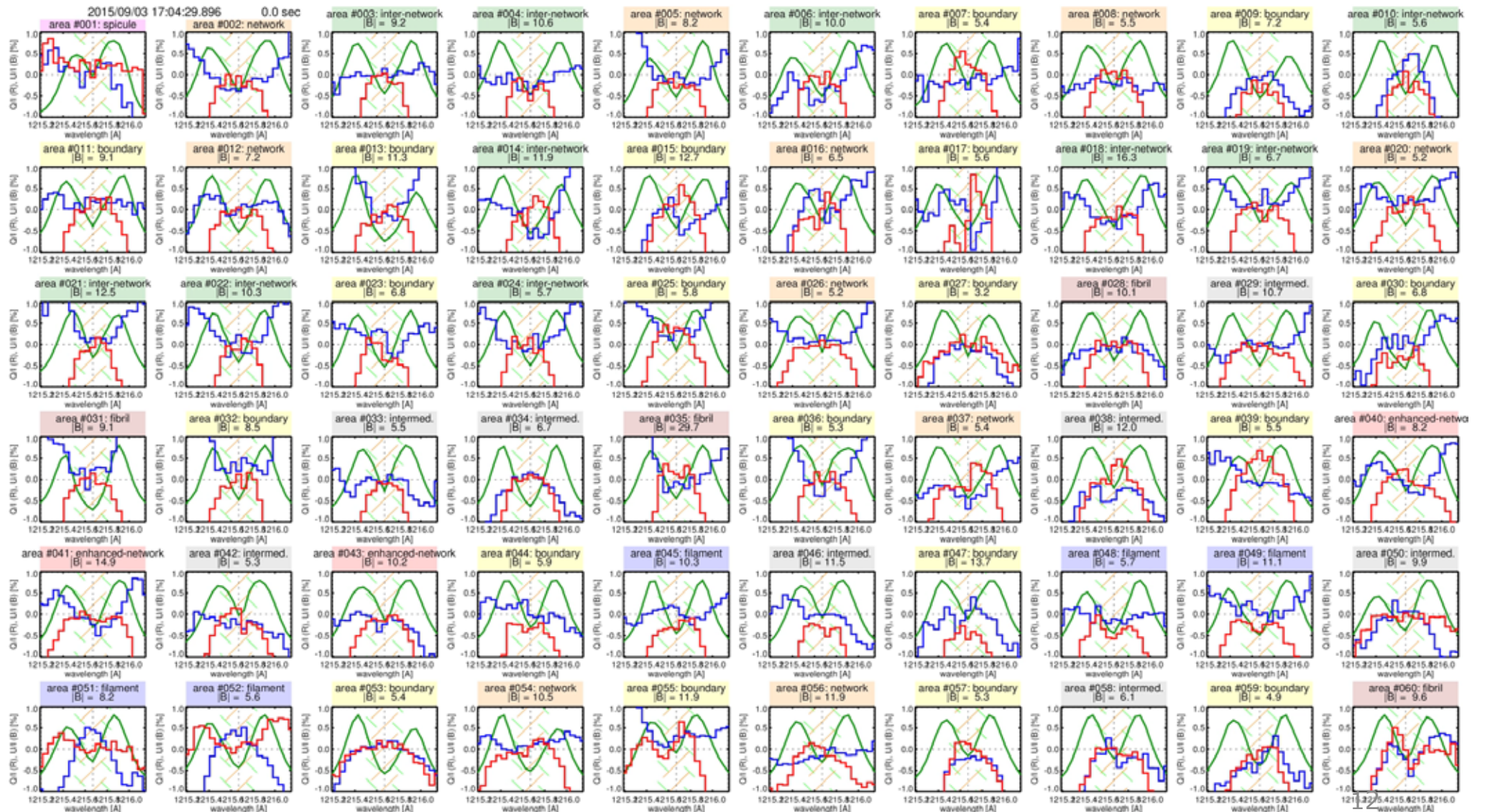
The region where the linear polarization spectrum is asymmetry.

- **Region near the solar limb:**
Asymmetry might be caused by the overlap of chromospheric structures along the line-of-sight.
- **Boundary region:**
Asymmetry might be caused by the effect from the bright neighborhood region.
- **Fibril, Filament:**
Asymmetry might be caused by the insufficient spatial resolution (too large binning) that cannot enough resolve the magnetic field structures.

Temporal binning

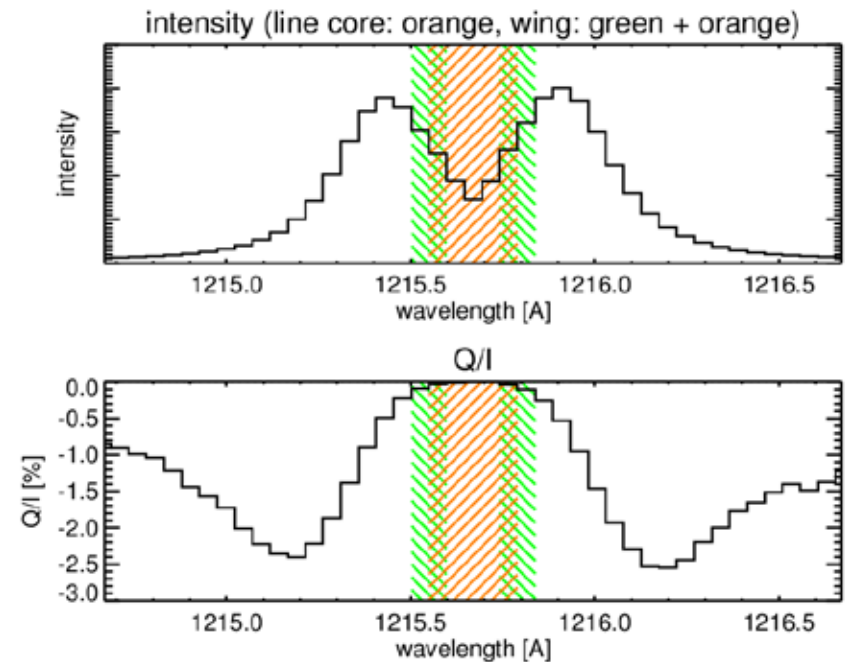
- The minimum temporal binning that can achieve the polarization accuracy of $2\sigma < 0.1\%$ is suitable to investigate the temporal variation.
- ➔ We perform the **binning with 72 modulation data (86.4 sec)** and discuss the temporal variation of the linear polarization with running sum data.

Temporal variation of the linear polarization spectrum

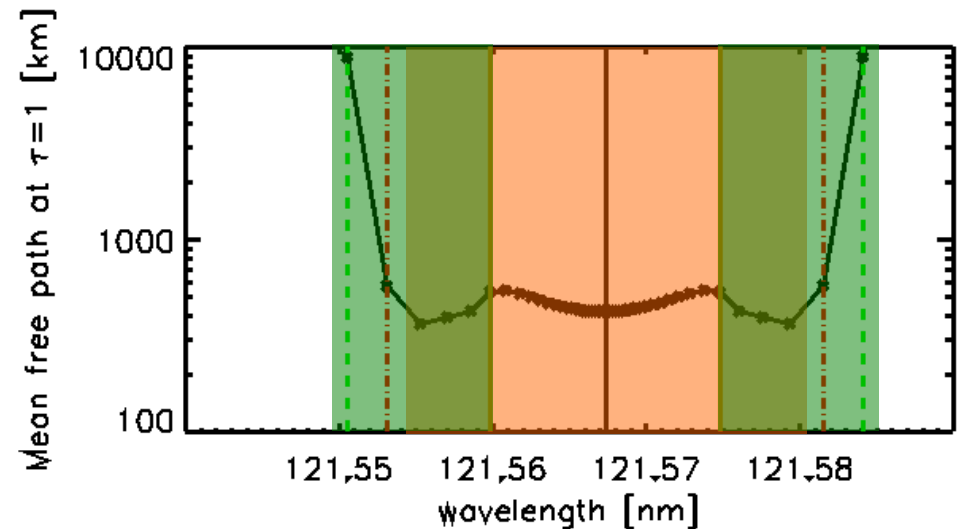
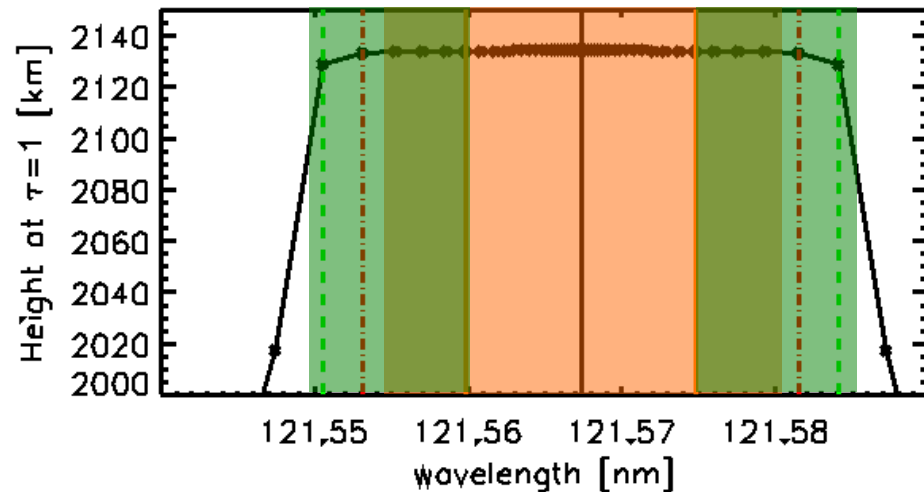
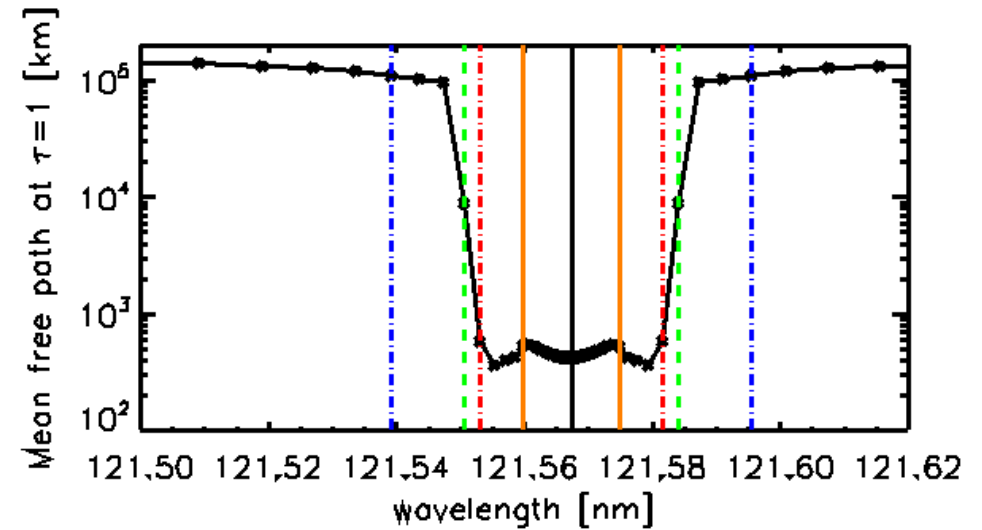
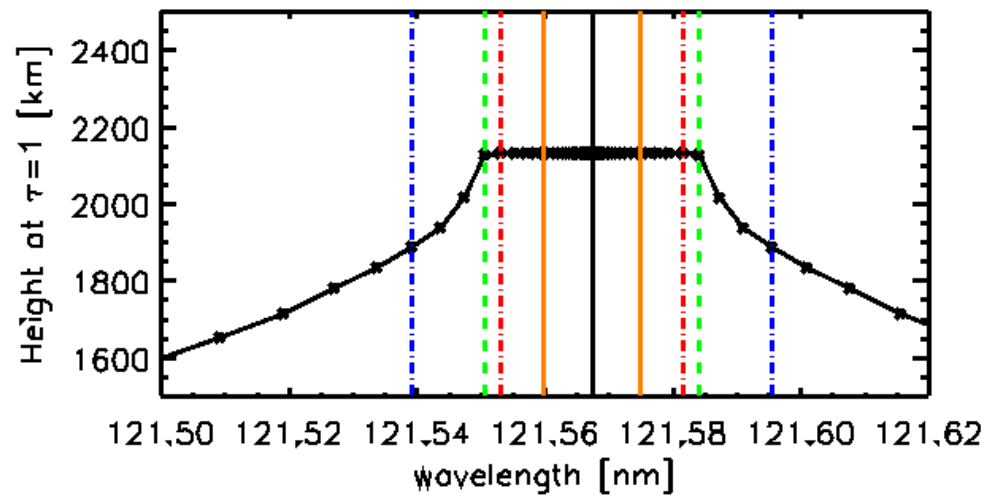


Spectral binning

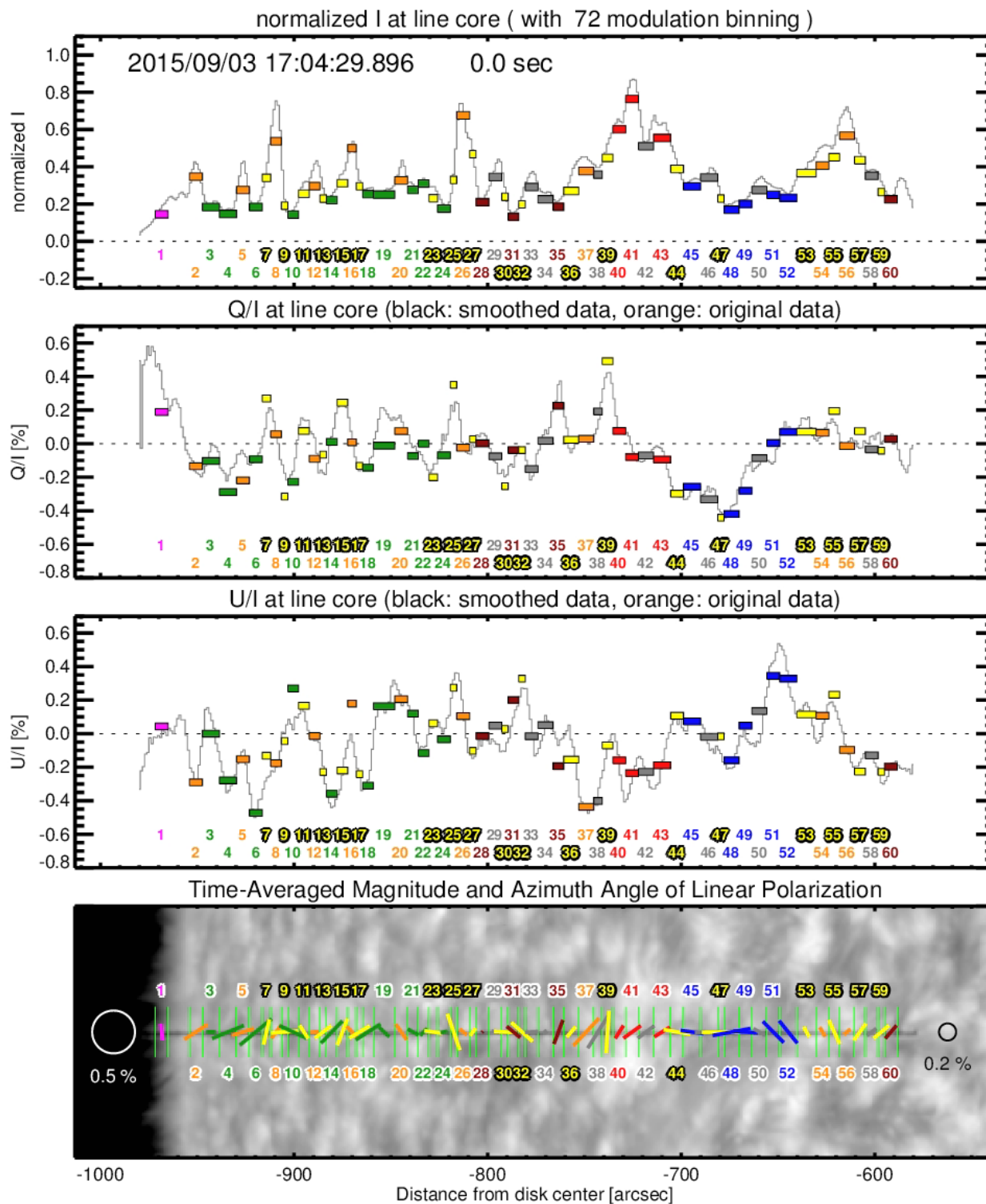
- We execute the spectral binning as follows:
 - CORE:
line center ± 0.010 nm
(5 pixels)
 - CORE SIDE:
line center $-0.015 \sim -0.010$ nm &
line center $+0.010 \sim +0.015$ nm
(4 pixels)
- In these spectral ranges (CORE and CORE SIDE), the “height of $\tau = 1$ ” and “mean free path” is similar. Then, we can consider that the emission from these ranges contains the similar plasma information (see next page).



$\tau=1$ height & effective mean free path



Temporal variation of linear polarization in Ly α (at CORE)

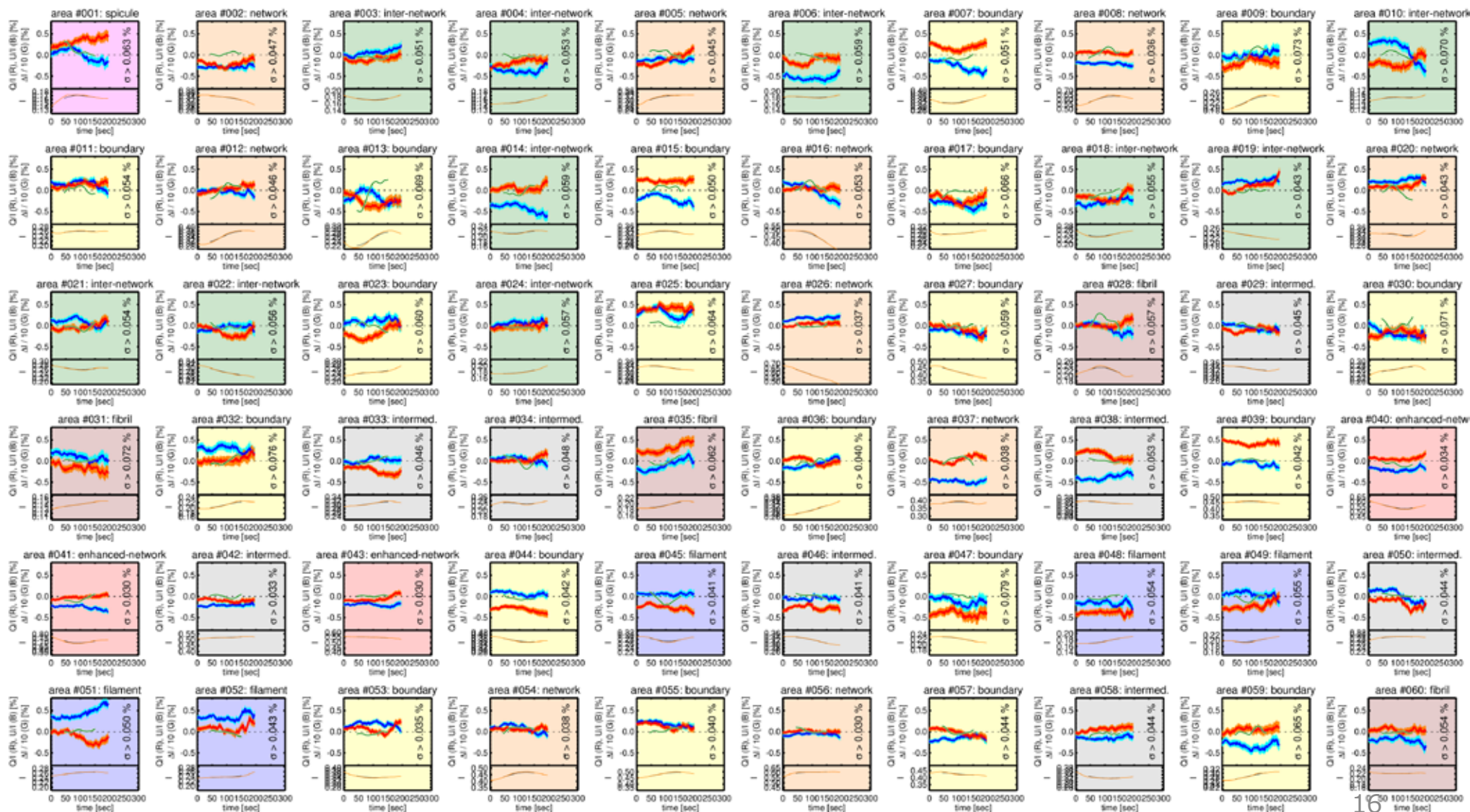


“enhanced network”, “network”,
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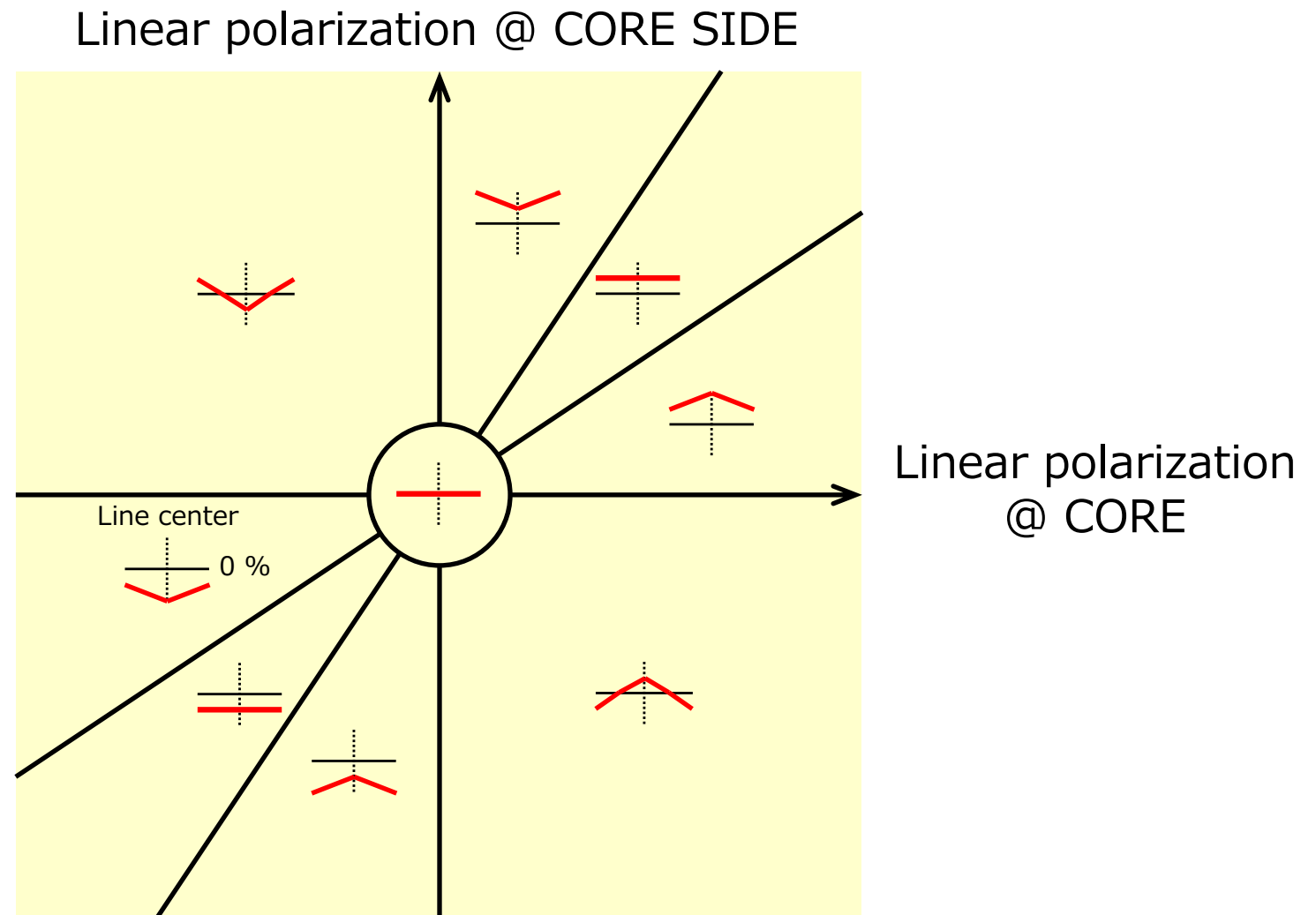
Temporal variation of linear polarization in Ly α (at CORE)

(with 2σ error bar)

“enhanced network”, “network”,
 “inter network”, “boundary”,
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 “spicule”

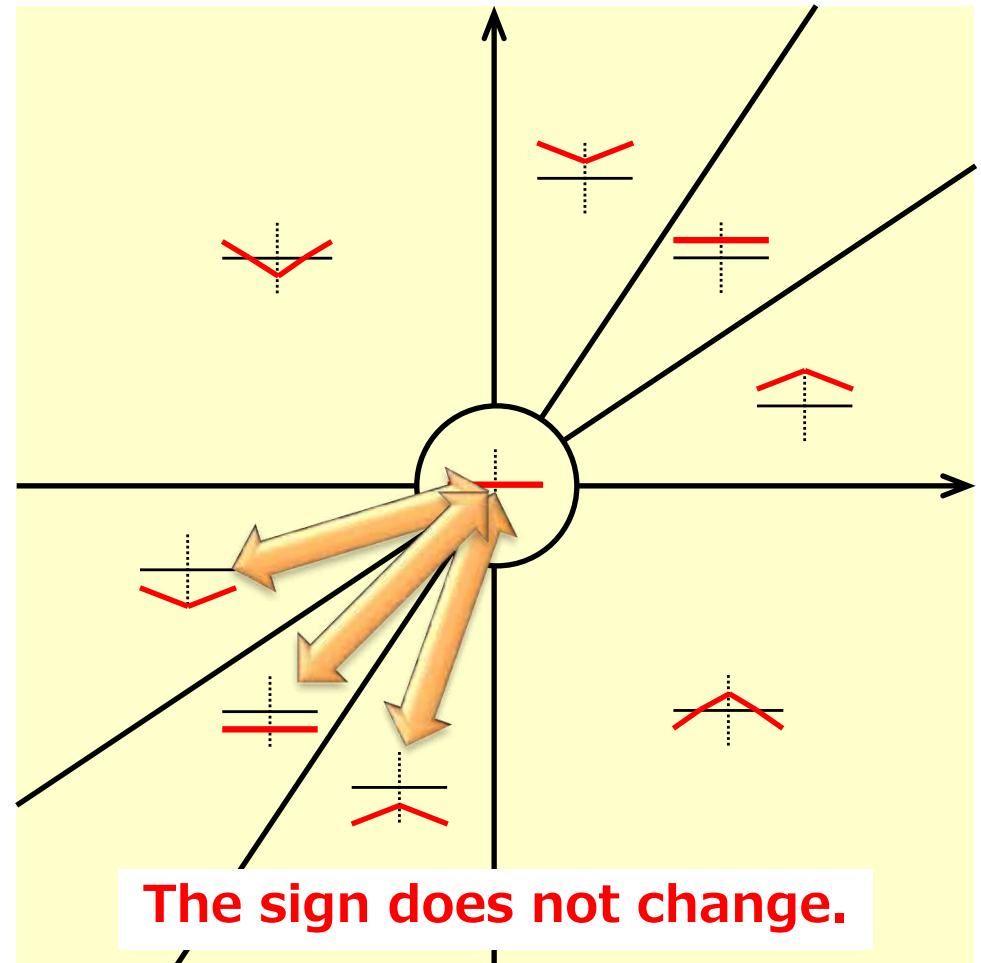
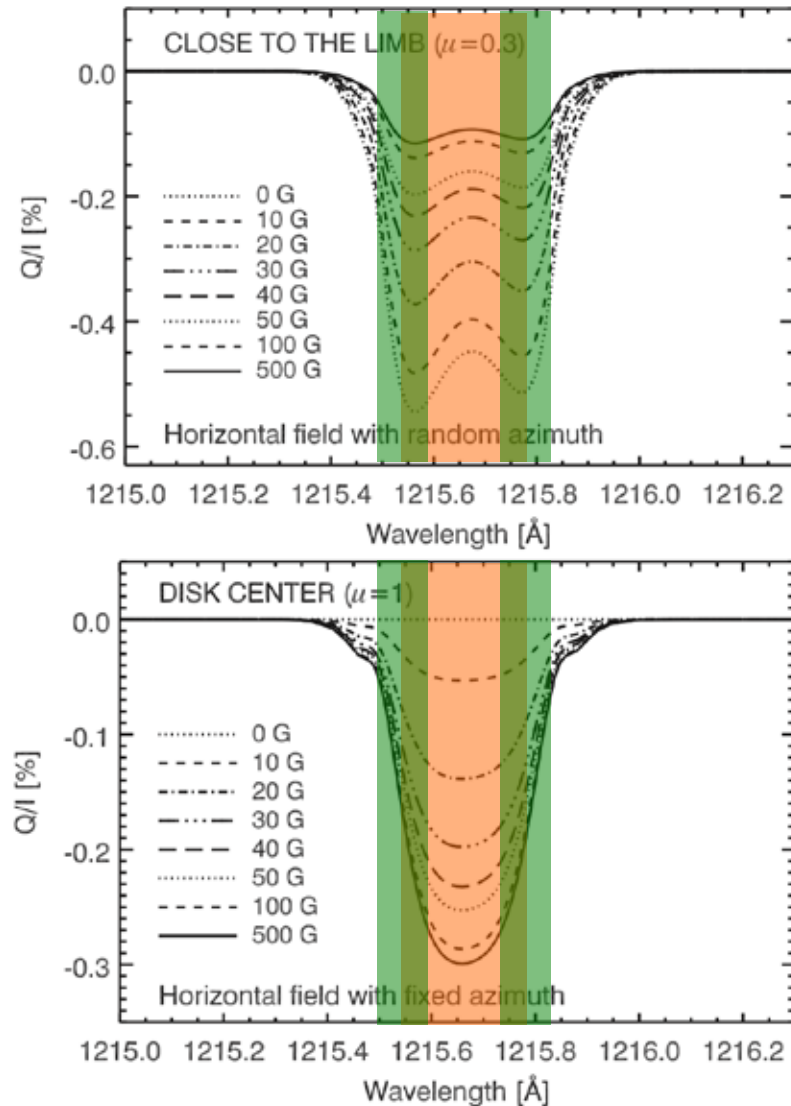


Classification of linear polarization



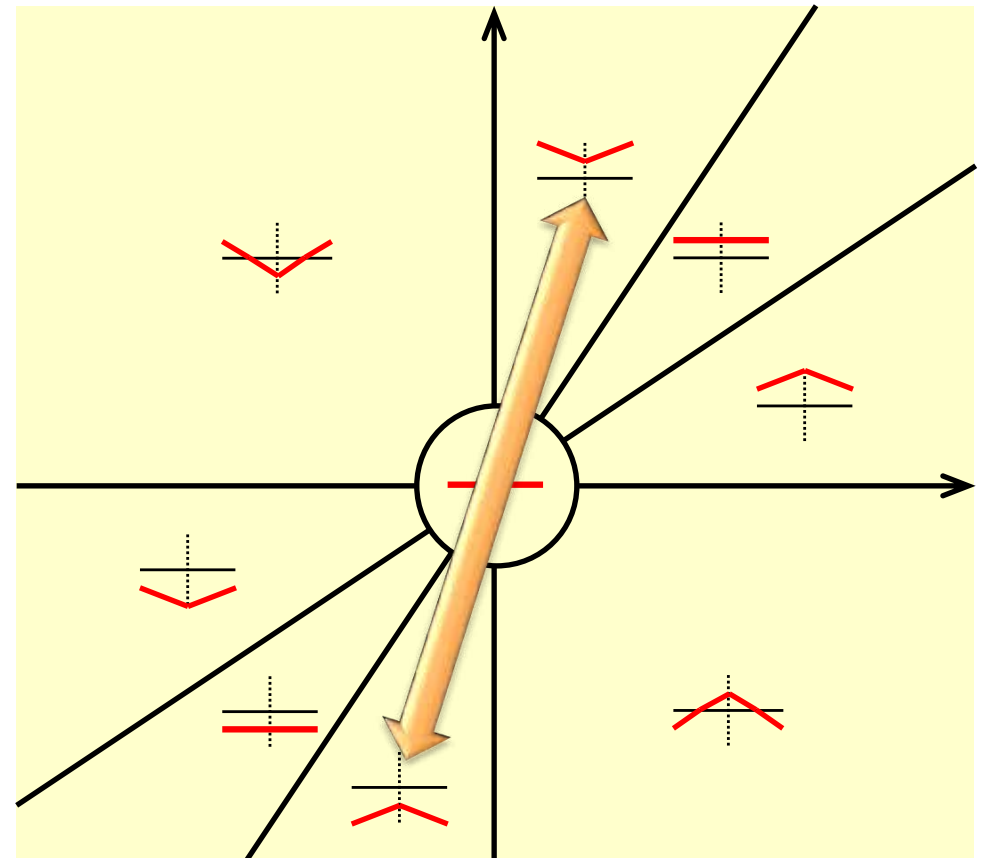
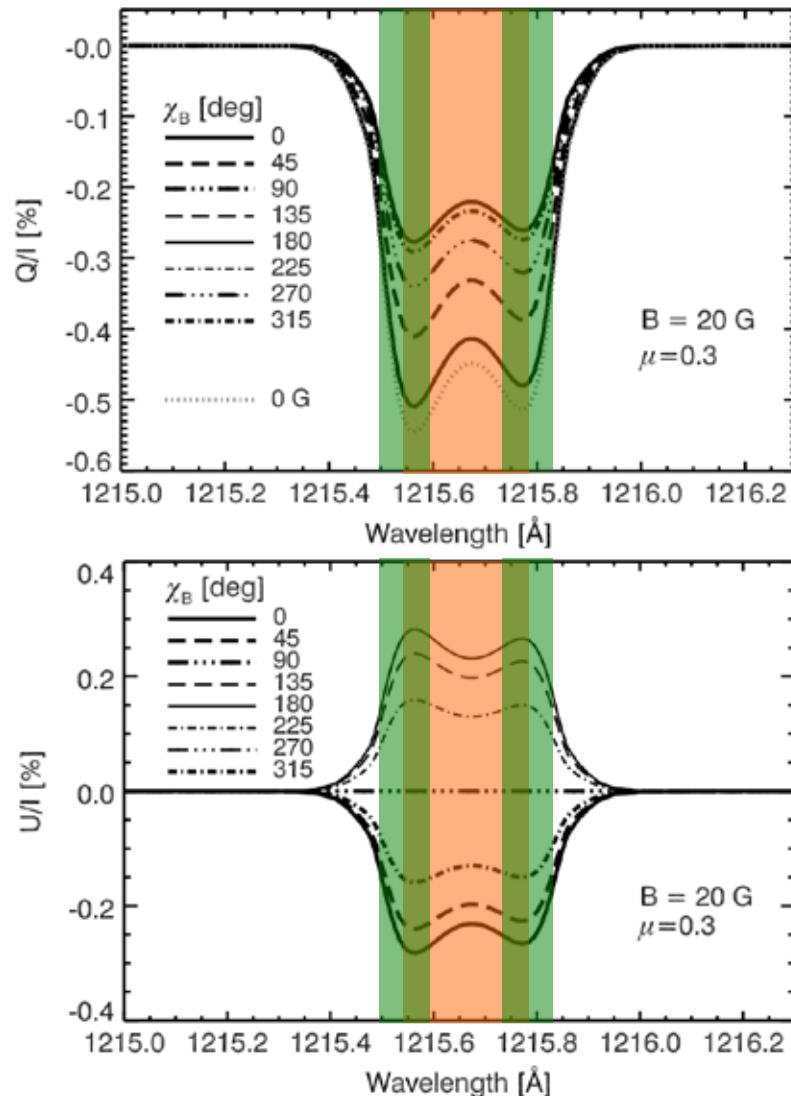
Meaning of this classicization [effect of magnetic field]

Variation of only B strength → The spectrum shape does not change significantly.



Meaning of this classicization [effect of magnetic field]

Variation of only B direction → The spectrum shape does not change significantly.



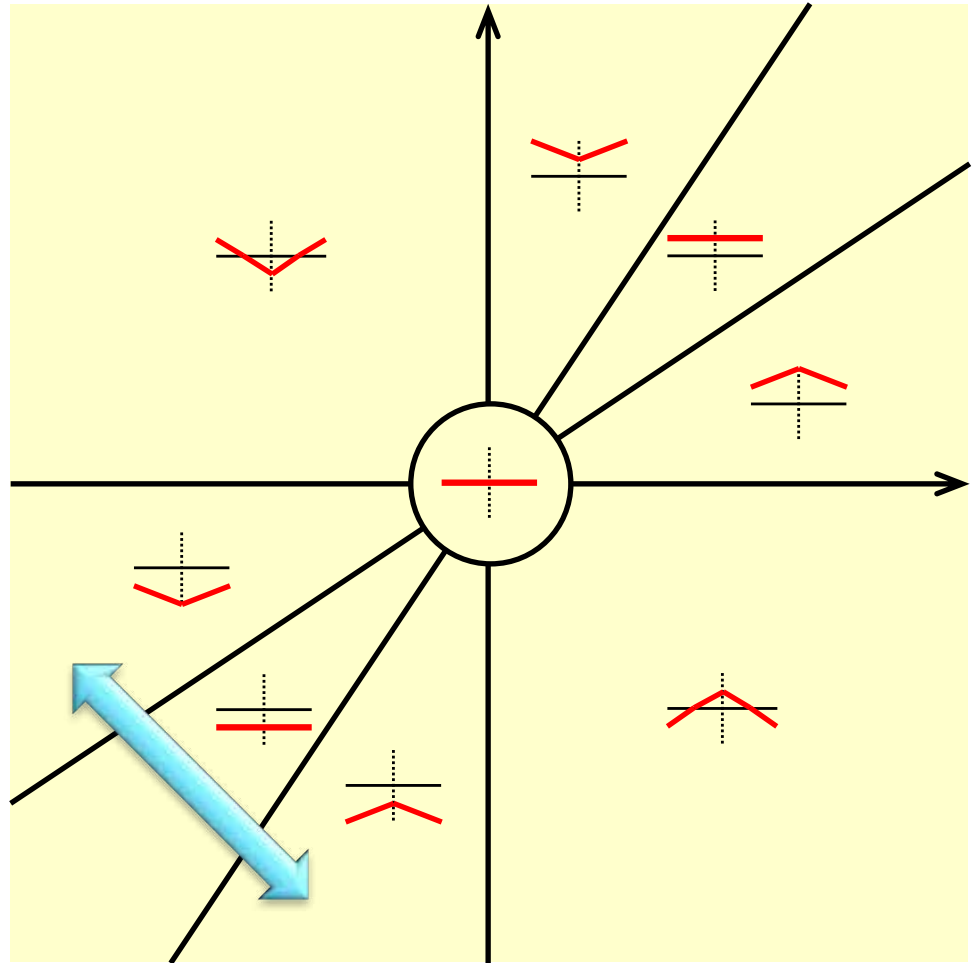
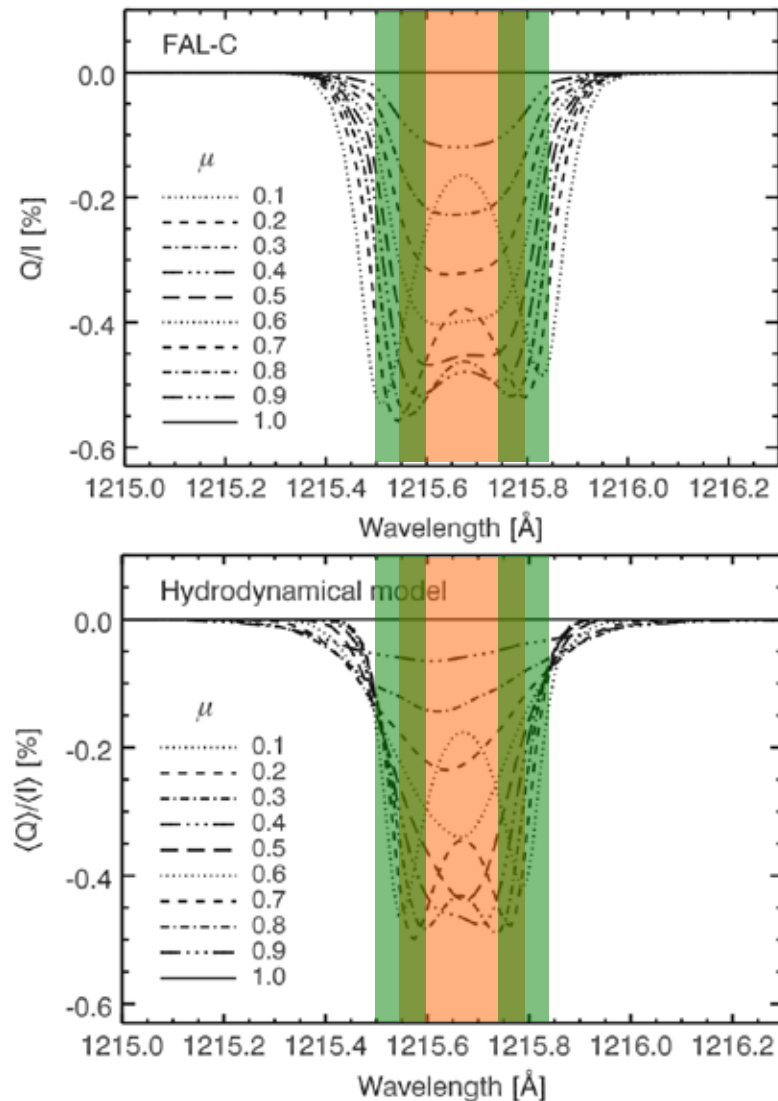
Q : negative value

U : both negative and positive values

Trujillo Bueno et al. (2011)

Meaning of this classicization [effect of magnetic field]

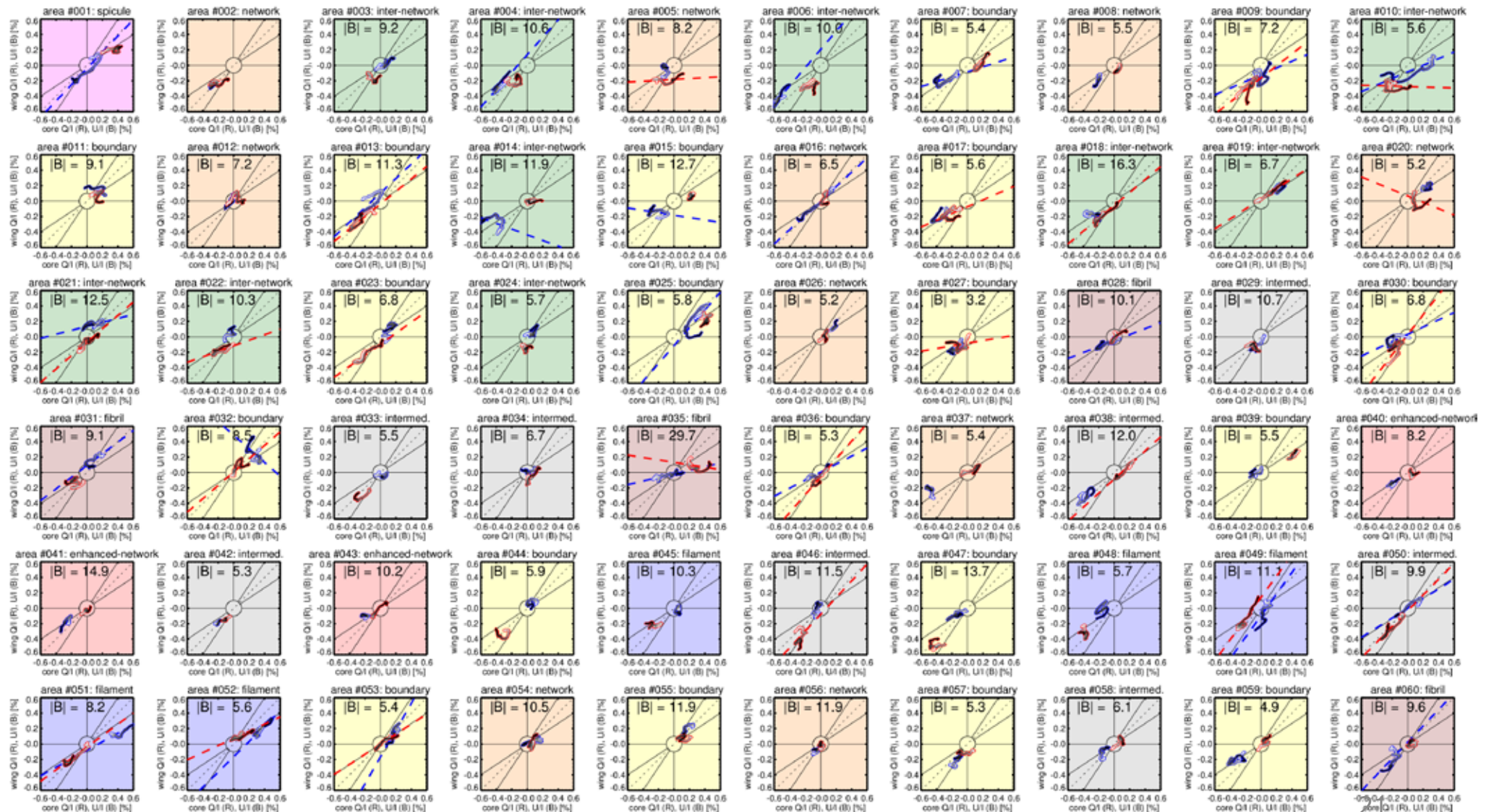
Variation of only μ (\sim radiation field) \rightarrow The shape of spectrum can vary.



Trujillo Bueno et al. (2011)

Classification of linear polarization

(For the variation of more than 0.3 %, we perform linear fitting as shown by dashed lines.)



Classification of linear polarization

(For the variation of more than 0.3 %, we perform linear fitting as shown by dashed lines.)

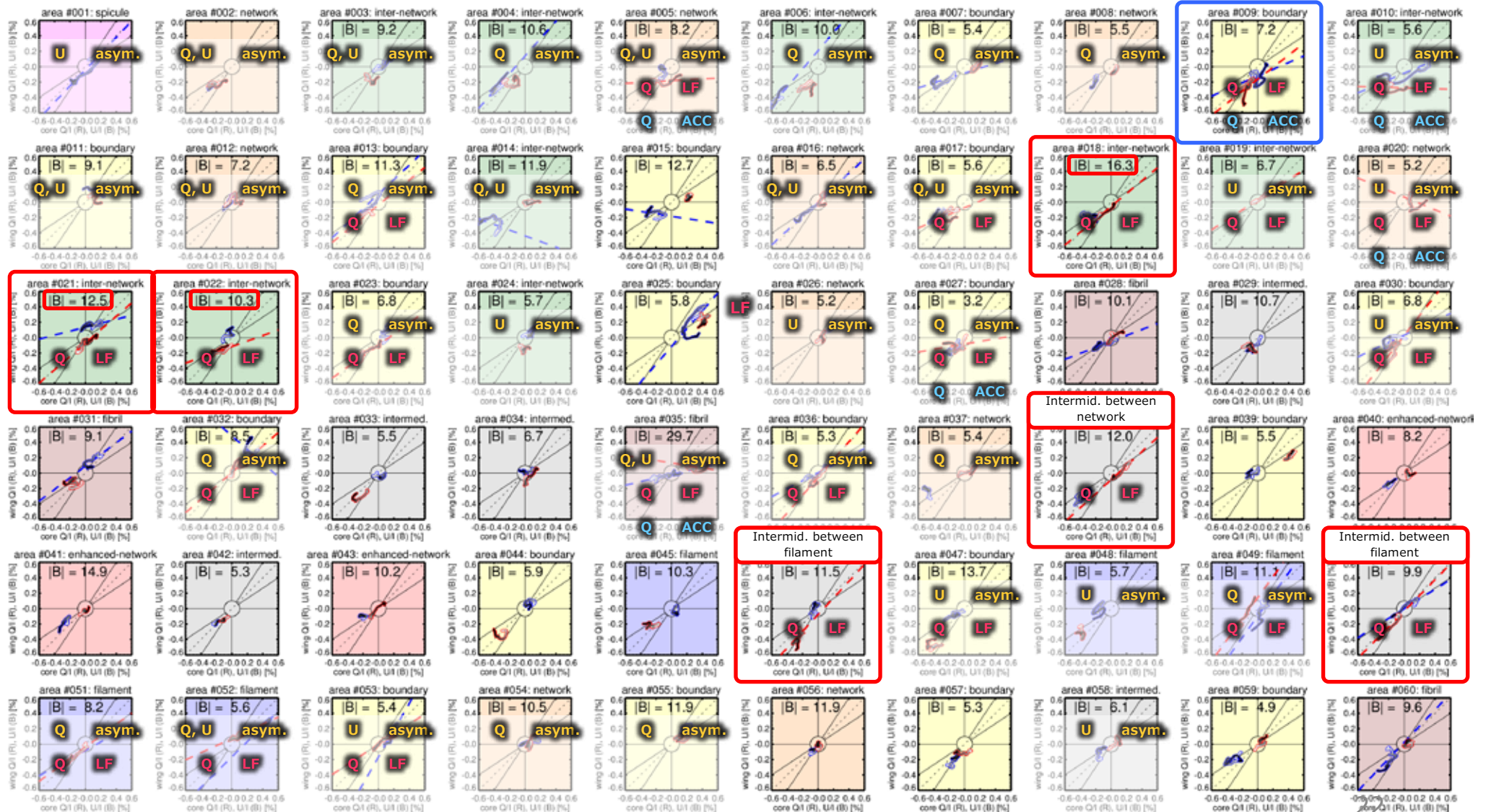
Effect of magnetic field

Effect of radiation field

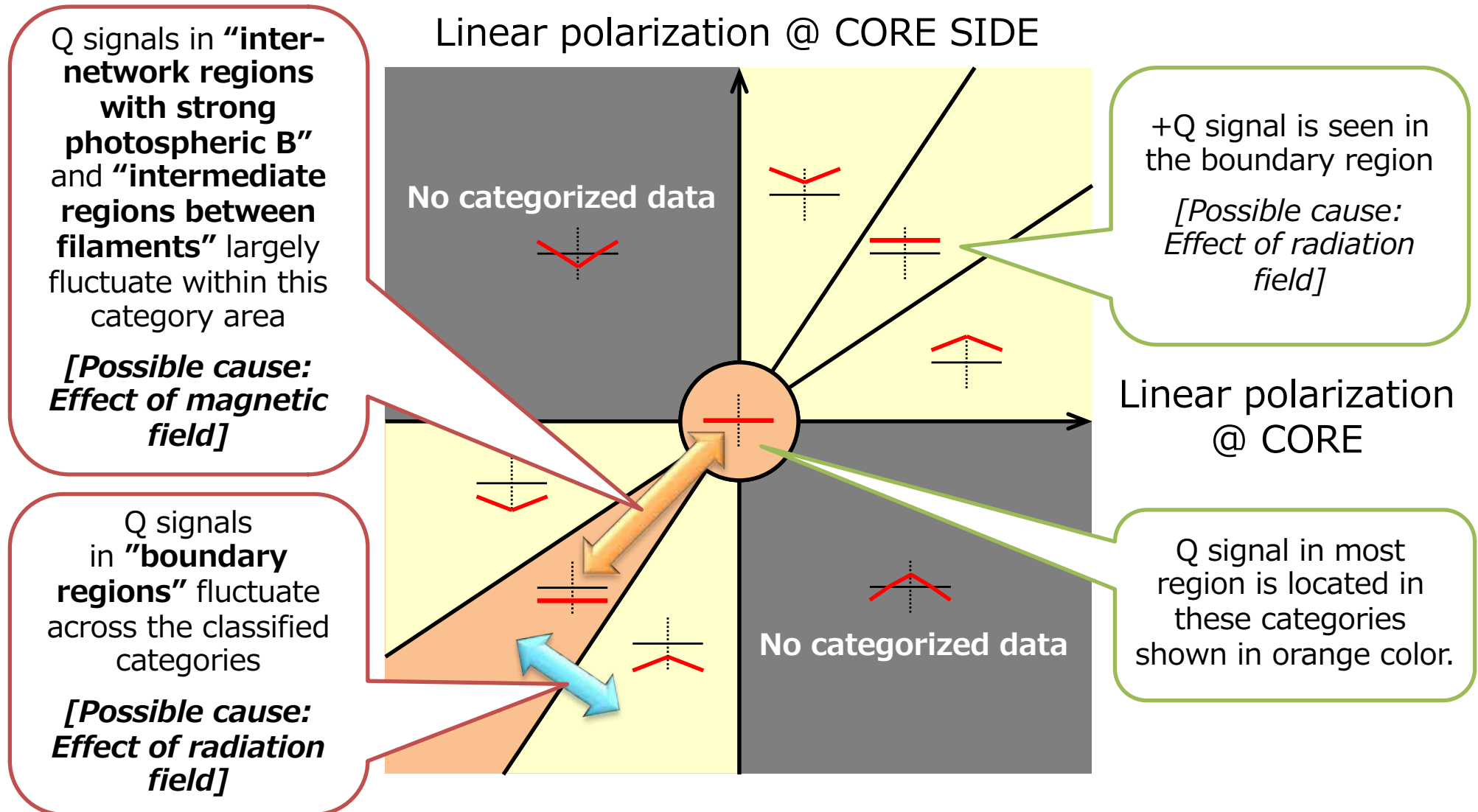
asym. = asymmetry in spectrum

LF = large fluctuation

ACC = across classified category



Summary of the classified linear polarization that have symmetry spectrum

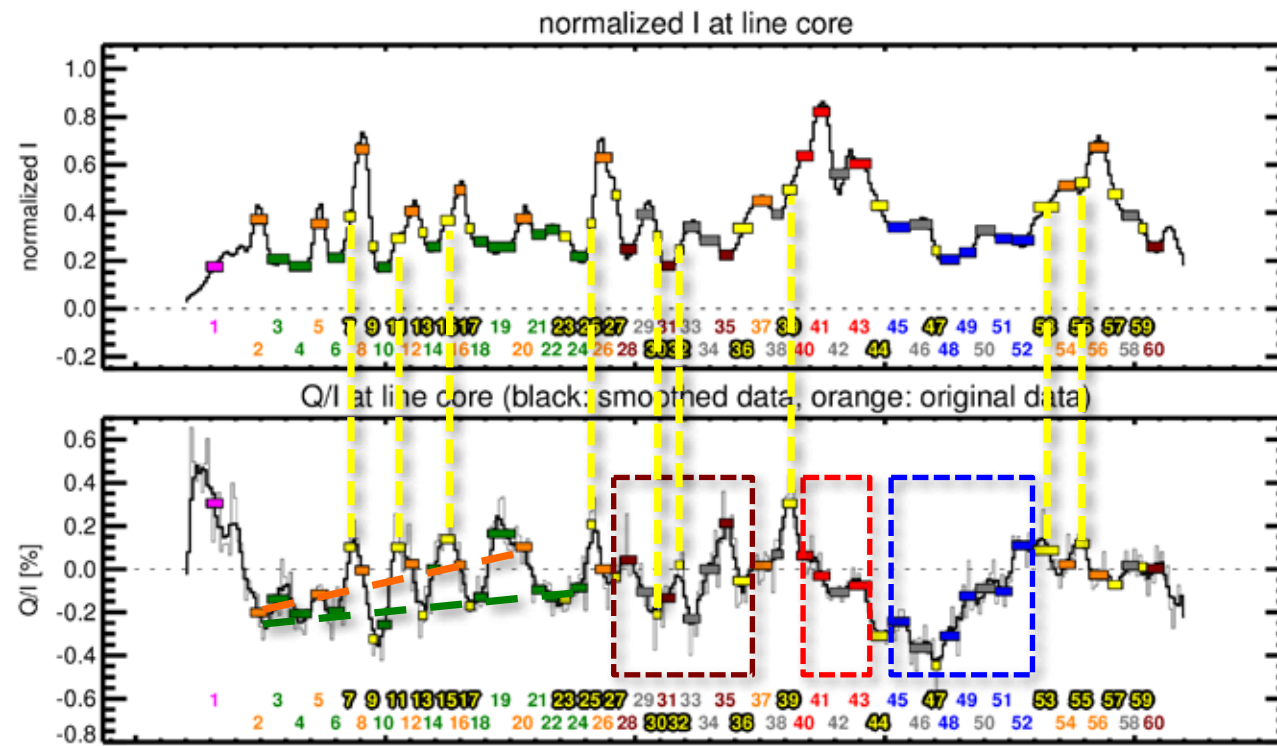


Summary

- The precise polarization measurement by CLASP makes us possible to track the temporal variation of the Ly α linear polarization with spectrum for the first time.
- This temporal variation gives us the hint to understand the fluctuation of radiation fields and magnetic fields.
 - For the detail understanding, we plan more analysis (namely, analysis of U-signal, analysis with other observational data (IRIS, AIA, HMI, etc.), comparison with models) as future works.

Appendix

Q偏光の興味深いトレンッド

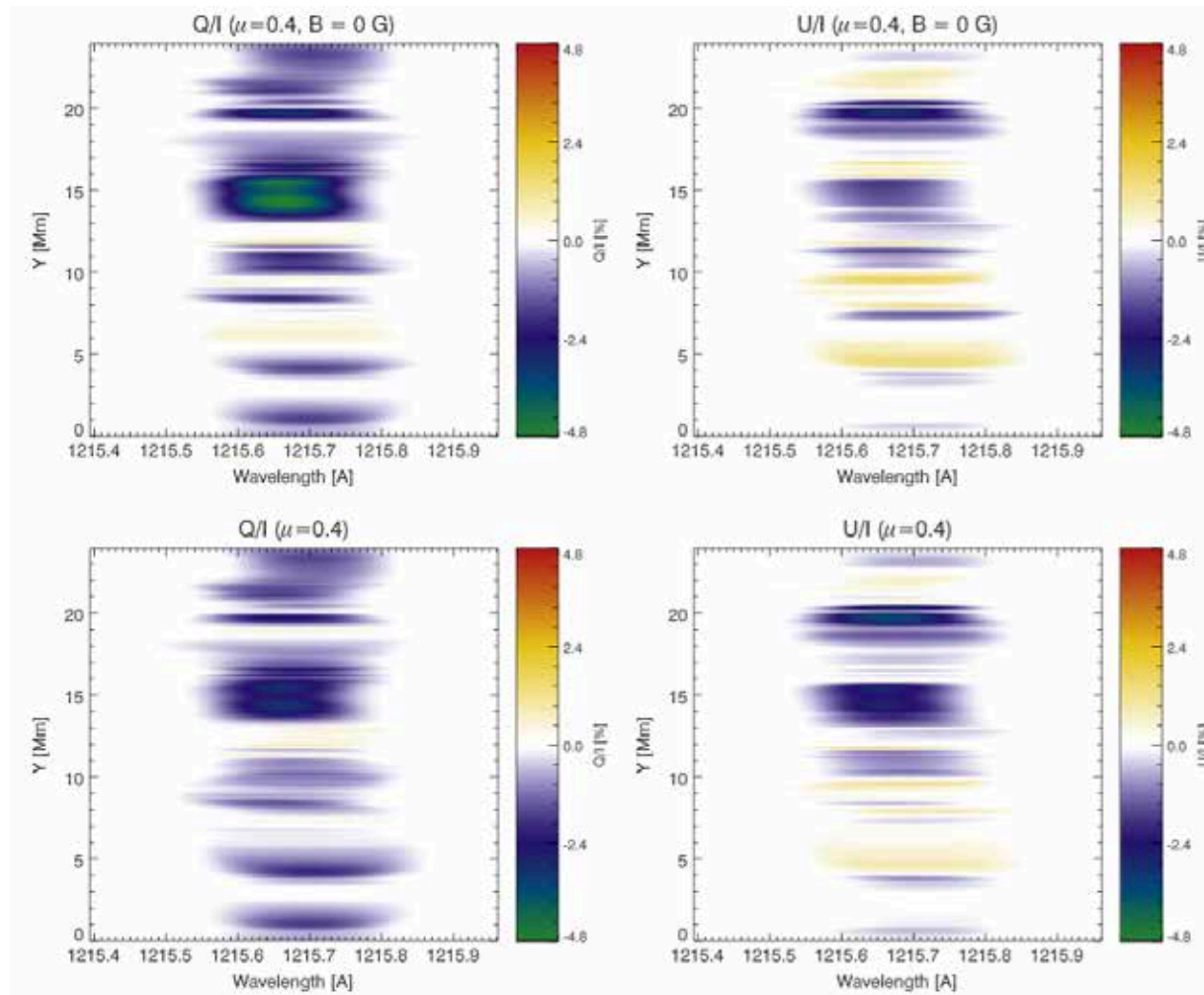


- Q が正の値を持つ領域は特別な領域（平行平板大気モデルではQは正の値を持たない）
 - リム側の **Boundary** 領域 ← 放射場の影響
- **Inter network**、**Network** と領域別に分けて見ると、center-to-limb variation が見える。

3次元数値計算 (Stepan et al., 2015)

時間変化を調べる計算は現在実行中

磁場なし



$B \sim 15$ G